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BAUMÉ STARCH CONCENTRATION RELATIONSHIPS FOR AQUEOUS SUSPENSIONS OF SWEETPOTATO STARCH AT DIFFERENT TEMPERATURES

By

D. M. Batson and J. T. Hogan

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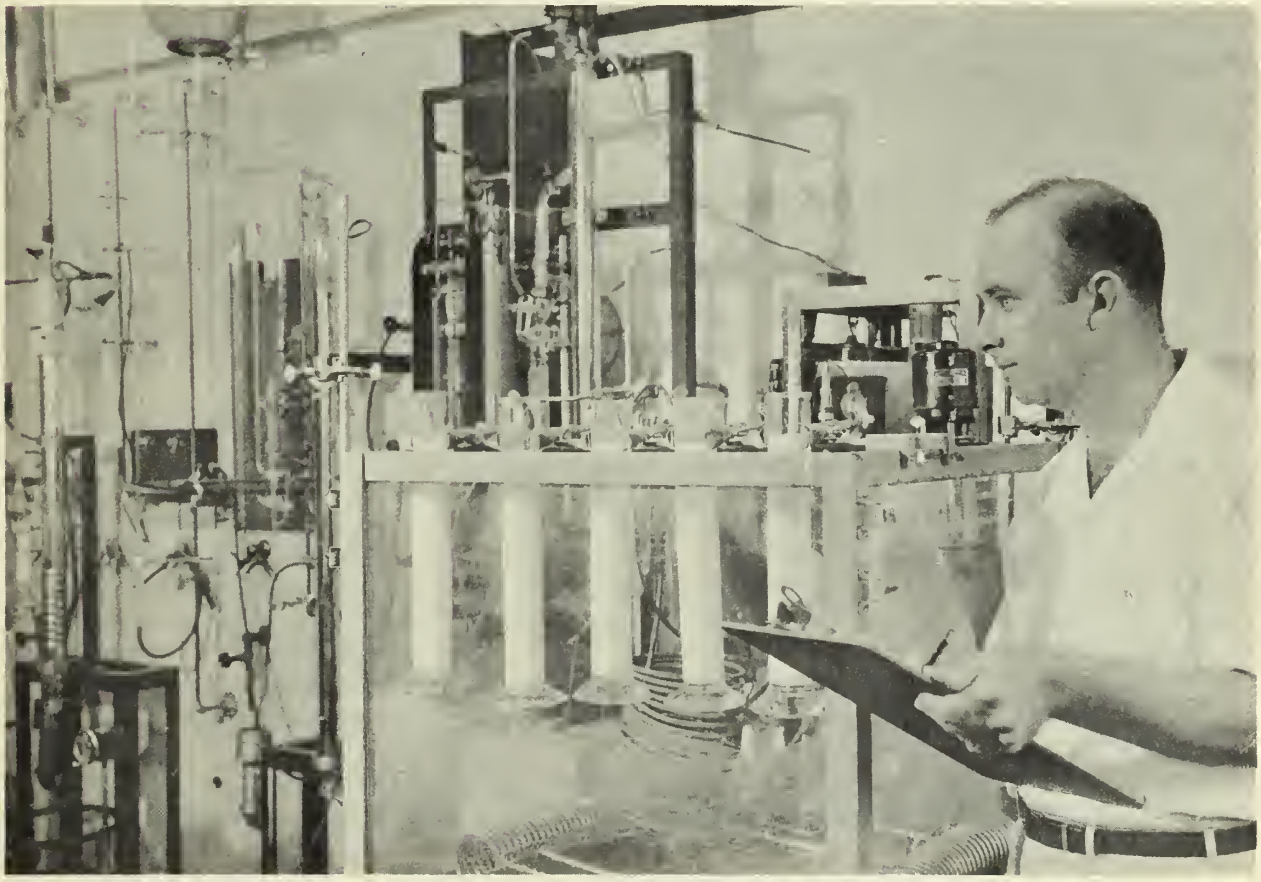

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INTRODUCTION

In the manufacture of starch from sweetpotatoes, as from other sources, factory operations require frequent estimations of the concentration of aqueous starch suspensions, or slurries, by means of a Baumé hydrometer. Producers of grain and tuber starches have long followed this procedure, and have used special tables to convert observed Baumé readings to terms of equivalent starch concentration. When commercial production of sweetpotato starch was undertaken in the factory which operated at Laurel, Mississippi, from 1934 through 1944, conversion tables based on other starches were utilized. Later the importance of using tables which are based on the particular starch under study and which give consideration to the effect of slurry temperature was shown by Cleland et al. (2) who presented the first Baumé-starch tables published in this country. Therefore, since there were no such data specifically applicable to sweetpotato starch, nor readily adaptable for use at different slurry temperatures within the 15°C. - 50°C. range of temperature extremes encountered in factory and experimental operations, the present study was undertaken.

METHODS

The relation between Baumé and starch concentration for a given starch may be determined approximately in a simple way by making Baumé hydrometer measurements on a series of starch suspensions containing various known weights of starch per unit volume. Since a change in slurry temperature changes this relationship a series of Baumé readings and starch determinations must be made at each of several different temperatures within the temperature range under consideration. A more accurate procedure by Cleland et al. (2) involved the use of a pycnometer for determining the density of starch-water slurries whose starch concentration at the temperature of the determination was known. Observed density, expressed as Baumé, was then correlated with starch concentration in each case. For convenience in the tabulation of data, however, these investigators used a series of factors based on the change in Baumé of water with a change in temperature since such results were found to agree closely with those obtained by the more tedious pycnometer procedure. In the present study it was decided that the necessary Baumé-starch data could be quickly and conveniently obtained by direct computations based on the densities of the two components of the slurry, namely, water and sweetpotato starch.

Reference tables showing the specific gravity equivalent of Baumé for liquids or suspensions having a density greater than unity are available. These tables, and also the Baumé hydrometer used in the United States, are based on a formula which states that at $\frac{60°F.}{60°F.}$

$$\text{(A)} \quad \text{Specific Gravity} = \frac{145}{145 - \text{Bé}}\text{, or}$$

$$\text{(B)} \quad \text{Bé} = 145\ (1 - \frac{1}{\text{Specific Gravity}}).$$

Specific gravity at 60°F. may be converted to terms of density by multiplying by the density of water at 60°F., and specific gravity referred to some other temperature may also be converted to density by multiplying by the density of water at that temperature. Thus density equivalent to Baumé is easily ascertained, and since Baumé is simply an arbitrary expression for density the relation between a given Baumé value and its corresponding density remains constant independently of slurry temperature. This indicates that even though the Baumé hydrometer is standardized for use at 60°F. it may be adapted to measurements at other temperatures.

Baumé-Starch Data at 15°C.

The apparent density of sweetpotato starch in aqueous suspension was determined in another study (1) and found to be 1.633 at 25°C.

The concentration of sweetpotato starch equivalent to each degree Baumé at 1°Bé intervals between 0°Bé and 25°Bé was computed for a suspension temperature of 15°C. as follows. Using reference tables to obtain Baumé-specific gravity values at 60°F., for this range in Baumé, the density, expressed in grams per liter, corresponding to each Baumé was found as mentioned above. (Although the reference data are for a temperature of 60°F., or 15.5°C., they were here used for 15.0°C., the error involved being insignificant). Thus, for water, which has a density of 0.99913 g. per ml. at 15°C. (Table 1) and a specific gravity referred to 15°C. of 1.000, the density in grams per liter, is 999.13. Taking the density of sweetpotato starch as 1.633, the density of water as 0.99913 g. per ml., and unit suspension volume as 1000 ml. all at 15°C. let

X = ml. volume of starch per unit volume of suspension

1000 - X = ml. volume of water per unit volume of suspension

Table 1. Absolute Density of Water at Indicated Temperatures

Temperature °C.	Density g./ml.
15	0.99913
20	0.99820
25	0.99707
30	0.99567
35	0.99406
40	0.99224
45	0.99025
50	0.98807

Then:

$$X(1.633) + (1000 - X)\ 0.99913 = \text{weight of 1 liter of starch and water suspension}$$

And:

$$X = \frac{(\text{Wt. of 1 liter of suspension}) - 999.13}{0.634}$$

Since: Volume x Density = Weight

$$X \times 1.633 = \text{Wt. starch per liter}$$

And:

$$\text{Grams starch per liter} = [(\text{Wt. of 1 liter of suspension}) - 999.13]\ 2.5737.$$

The values for "Grams starch per liter" were converted to "Percent starch by weight" by means of the equation:

$$\text{Percent starch} = \frac{\text{Grams starch per liter}}{\text{Wt. of 1 liter of suspension}} \times 100,$$ and to "Pounds starch per gallon" by the equation:

$$\text{Pounds starch per gallon} = \text{Grams starch per liter} \times 0.008345.$$

The results obtained are given in Table 3-A under the temperature column headed 15°C.

In order to check the validity of the computed Baumé-starch data a series of aqueous suspensions of starch containing known weights of sweetpotato starch per liter at 15°C. were prepared. The suspensions were maintained at 15°C. and the Baumé of each was carefully measured. In every case the observed Baumé was in excellent agreement with the theoretical or expected value. Further, it was noted that the calculated starch values agreed almost perfectly with those of Cleland *et al*. (2) for corn starch which had a density of 1.636 at 15.5°C.

Baumé-Starch Data Above 15°C.

It was desired to obtain additional Baumé-starch data of this type for interpreting hydrometer measurements made at temperatures above 15°C. In order to do this, consideration was given to the fact that starch suspensions consist of two principal components, starch and water. Obviously both components increase in volume, or decrease in density, with an increase in temperature. The density of water at different temperatures between 15°C. and 50°C. is shown in Table 1. No such information concerning sweetpotato starch, or any other starch, was available, however, so preliminary determinations of the density of sweetpotato starch at several temperatures other than 25°C. were made. Using these densities and the data in Table 1 a series of Baumé-starch concentration values for each slurry temperature were computed. On the other hand, additional calculations were made by using an unvarying figure of 1.633 for starch density, and thus giving no consideration to the effect of temperature on starch density. The results obtained by the two procedures of computation were compared in order to determine whether thermal effects on starch density might be disregarded, since the net effect upon Baumé-starch relations produced by changes in starch density was expected to be of small magnitude. This expectation was proved valid by the comparison; for example, in the case of a slurry at 15°Bé and 40°C. the value for percent starch by weight obtained on the basis of a starch density value determined at 40°C. was 28.17 compared to 27.93 found by the second computation procedure. The close agreement between results obtained by the two procedures indicated that the error induced by failing to allow for changes in starch density with changes in temperature was small. Further, the error was within the limits of accuracy required for use of the computed data under factory conditions, and also is even less than the single error inherent to reading the Baumé hydrometer in starch slurries under such conditions. Accordingly, in order to facilitate calculations, no allowance for starch density changes was made, and the previously established value for sweetpotato starch density of 1.633 at 25°C. was accepted as being valid for all slurry temperatures.

Baumé-starch concentration data for slurries at temperatures above 15°C. were computed. For this purpose it was assumed as a hypothetical case that a 1-liter volume of starch-water suspension having a specified original Baumé at a temperature of 15°C. was adjusted successively to a number of higher temperatures. The original Baumé values considered were 0° (water), 5°, 10°, 15°, 20°, and 25°, and the temperatures were 20°, 25°, 30°, 35°, 40°, 45°, and 50°C. With the aid of the data in Table 1 showing density of water at each temperature, and the data for Baumé versus starch concentration at 15°C., the expected or theoretical Baumé-starch relationships ultimately prevailing at other temperatures were ascertained in the manner described in the following paragraphs.

To find the theoretically correct Baumé of water at the various temperatures in question the values in Table 1 for density of water were converted to terms of "Specific gravity at 15°C." by dividing each by the density of water at 15°C. Each specific gravity value was then substituted in formula (B) above to obtain the Baumé values for water given in Table 2.

Table 2. Computed Baumé and Percent Starch by Weight Values Showing the Effect of Temperature on Water and on Starch-Water Suspensions Having the Specified Original Baumé Values and Percent Starch Contents

Original Baumé at 15°C.	Percent Starch (at 15°C.)[1]	Baumé at Indicated Temperatures						
		20°C.	25°C.	30°C.	35°C.	40°C.	45°C.	50°C.
0.00 (water)	0.00	-0.13	-0.29	-0.49	-0.74	-1.00	-1.29	-1.61
5.00	8.85	4.89	4.73	4.52	4.32	4.07	3.80	3.51
10.00	17.75	9.89	9.76	9.58	9.38	9.16	8.93	8.64
15.00	26.62	14.91	14.78	14.64	14.46	14.26	14.05	13.81
20.00	35.50	19.91	19.81	19.68	19.53	19.35	19.17	18.95
25.00	44.37	24.92	24.82	24.71	24.58	24.43	24.27	24.08

1/ These percent starch figures are also valid for the other specified temperatures.

It should be pointed out that water at 15°C. (correctly 15.5°C.) has a Baumé of zero; so, since an increase in temperature decreases its density, the Baumé of water at temperatures above 15°C. necessarily becomes a negative value.

In the case of a starch-water suspension of given original Baumé at 15°C., the Baumé which it should have if warmed to any specified higher temperature was found by substituting approrpiate data from Table 1 and Table 3-A in the following schedule, with D, V, T_1, G, and b being constants in all cases. Each series of computations yielded a single Baumé value and its corresponding percent starch value.

Let:

D = starch density, 1.633
V = unit suspension volume, 1000 ml.
T_1 = original suspension temperature, 15°C.
T_2 = one of the higher suspension temperatures specified in Tables 3-A and 3-B.
G = 0.99913, the density of water at 15°C.

Then, expressing volumes in milliliters and weights in grams, we have:

a = Baumé of original suspension
b = vol. of original suspension
c = wt. of starch in original suspension
d = vol. of starch in original suspension = $\frac{c}{D}$
e = vol. of water in original suspension = b - d
f = wt. of e ml. at T_1 = e x G
g = absolute density of water at T_2
h = vol. of water in total expanded suspension = $\frac{f}{g}$
i = increase in suspension volume = h - e
j = vol. of thermally expanded suspension at T_2 = b + i
k = wt. starch in 1 liter of the suspension at T_2 = $(c \times \frac{b}{j})$
l = vol. of k gms. of starch = $\frac{k}{D}$
m = vol. water in 1 liter of the suspension at T_2 = V - l
n = wt. of m ml. water at T_2 = m x g
o = wt. of 1 liter of the suspension at T_2 = k + n
p = absolute density of the suspension at T_2 = $\frac{o}{V}$
q = specific gravity of the suspension, referred to 15°C. = $\frac{p}{G}$
r = computed Baumé of the suspension at T_2 = $145\ (1 - \frac{1}{q})$
s = percent starch by weight in the suspension at T_2 = $\frac{k}{o} \times 100$.

RESULTS

The computed values for Baumé and percent starch obtained by the foregoing procedure are summarized in Table 2.

Table 2 shows the Baumé which will be attained by each slurry of given original Baumé if the slurry temperature is increased to the indicated levels. It will be noted that both for water and for starch-water slurries the change in Baumé per 5°C. increase in temperature is greatest at higher temperatures, and also is greater for dilute slurries than for the more concentrated ones. Both of these trends merely reflect the effect of temperature upon the density, or Baumé, of water.

It is apparent that if attained Baumé in each case is subtracted from original Baumé the data in Table 2 would yield a series of Baumé correction factors of the type given by Cleland *et al*. (2).

A large-scale graph based on the data in Table 2 was constructed on rectangular-coordinate paper, with Baumé plotted on an abcissa scale of 1 inch = 1°Baumé and percent starch on an ordinate scale of one-half inch = 1 percent starch. Suspension temperature was the third variable. A rectilinear relationship exists between the first two variables so a family of straight lines was obtained, with a separate line for each temperature. From this graph the percent starch values given in Tables 3-A and 3-B were read directly with the aid of a hand lens. With regard to the other data in these tables, the values for grams starch per liter were found by multiplying weight of 1 liter of suspension by percent starch; and values for pounds starch per gallon were obtained by multiplying grams starch per liter by the factor 0.008345. All starch values refer to moisture-free starch.

In Tables 3-A and 3-B the indicated relationships between Baumé and weight of 1 liter of suspension are valid for all suspension temperatures since the weight values actually are density values expressed in grams per liter. To use these tables for converting Baumé hydrometer readings to terms of starch concentration select the column group whose temperature heading agrees most closely with the temperature of the suspension in question. If the observed Baumé is a whole number, locate this Baumé value in the table. Then, horizontally opposite the Baumé figure find in the selected column group the starch concentration expression sought. If the observed Baumé is a fraction, interpolate between the proper starch-concentration values.

Tables 3-A and 3-B were also used in laboratory studies on the acid-modification of sweetpotato starch as an aid in the preparation of sweetpotato starch-water suspensions which would possess certain desired Baumés at chosen suspension temperatures. This use may be illustrated by the following example: Suppose that it is desired to prepare one liter of suspension whose Baumé will be 5.0° at a suspension temperature of 40°C. The table shows that such a suspension will weigh 1034.8 grams and contain 108.3 grams of starch (moisture-free weight). Therefore the weight of water required will be 1034.8 - 108.3 or 926.5 grams, so if a suspension consisting of 108.3 grams of starch and 926.5 grams of water (including starch moisture) is adjusted to a temperature of 40°C. it will have a

Baumé of 5.0° and a volume of exactly one liter. In practice an allowance must of course be made for the weight of water present as moisture in the starch sample taken.

Experimental Verification of Computed Data

It was previously mentioned that in Tables 3-A and 3-B the percent starch values for suspensions of a given temperature above 15°C. were all read from the same straight line on a graph and each suspension temperature was represented on this graph by a different straight line. Then, in order to prove that the percent starch values taken from a single straight line are correct it was only necessary to prove that the position and slope of the line were correct. This could be accomplished by experimentally verifying the correctness of two points or values on that line. (Since the three expressions for starch concentration, namely, percent starch, grams per liter, and pounds per gallon are mutually equivalent in each case, then if one expression such as grams per liter is found valid the other two will likewise be valid). To do this the tabular data were used in the manner described for acid modification studies. Two suspensions of different starch concentration were prepared for Baumé measurement at one temperature, one suspension being expected to have a Baumé of 5.0° and the second a Baumé of 15.0°. Eight such pairs of suspensions were prepared, one pair for each of the eight suspension temperatures. The test suspensions were made up on a weight basis, using the appropriate values from the tables for grams per liter and weight of 1 liter of suspension and working with sweetpotato starch of known moisture content. The weighed quantities of starch and water were mixed for 1 hour with a mechanical stirrer to insure disintegration of aggregates and complete wetting of the starch. The slurry was transferred to a hydrometer cylinder, placed in a constant temperature bath, and the slurry carefully agitated by means of a metal rod bearing a perforated disk at its lower end. When the slurry reached the desired temperature a Baumé measurement was made with an accurate hydrometer. The average of three successive readings was taken as the observed Baumé of that slurry.

The observed Baumé of each test suspension agreed with the theoretical or expected Baumé within 0.2°Bé in every case. This excellent agreement indicates that the computed data in Tables 3-A and 3-B are correct, and the table may therefore be used for converting the results of Baumé hydrometer measurements to terms of starch concentration.

Thus far no mention has been made of correcting for thermal expansion of the hydrometer nor of correcting for meniscus error. The former type of error is small in magnitude, usually being equivalent to less than 0.1°Bé, and accordingly need not be considered. Meniscus error, reported elsewhere (2) as 0.08° Bé, appeared in this study to be approximately 0.1°Bé in most cases, and was greatest in highly concentrated slurries. This error, however, was also disregarded because it is no greater than the error inherent to reading a hydrometer in the average frothy slurry under factory conditions. In general, hydrometer measurements are satisfactory if accurate to within 0.2° Baumé.

SUMMARY

A method for computing Baumé-starch concentration data for aqueous suspensions of sweetpotato starch is described. The computations are based on a determined value for the density of sweetpotato starch and on the known relationship between density of water and temperature. A master table showing computed relationships between Baumé, starch concentration, and suspension temperature for each degree Baumé between 0° and 25°Bé and for suspension temperatures at 5°C. intervals between 15°C. and 50°C. inclusive is presented. The table is suitable for both starch factory and laboratory use for interpreting Baumé hydrometer readings in terms of starch concentration. The validity of the computed data is verified experimentally.

LITERATURE CITED

(1) Batson, D. M., and Hogan, J. T. Anal. Chem. 21, 718-721, 1949.

(2) Cleland, J. E., Fauser, E. E., and Fetzer, W. R. Ind. Eng. Chem. Anal. Ed. 15, 334-336, 1943.

Table 3-A. Computed Data for Aqueous Suspensions of Sweetpotato Starch Showing the Relationship Between Baumé and Starch Concentration at Different Suspension Temperatures

Baumé of Starch Suspension	Specific Gravity at 15°C. Equivalent to Baumé	Weight of 1 Liter of Starch Suspension (Grams)	Starch Concentrations at Indicated Suspension Temperatures											
			15°C.			20°C.			25°C.			30°C.		
			Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon
0.0	1.0000	999.1	0.00	0.0	0.000	0.23	2.3	0.019	0.55	5.5	0.046	0.92	9.2	0.077
1.0	1.0069	1006.0	1.77	17.8	0.149	2.00	20.1	0.168	2.31	23.2	0.194	2.67	26.9	0.224
2.0	1.0140	1013.1	3.55	36.0	0.300	3.77	38.2	0.319	4.05	41.0	0.342	4.41	44.7	0.373
3.0	1.0211	1020.2	5.32	54.3	0.453	5.52	56.3	0.470	5.83	59.5	0.497	6.17	62.9	0.525
4.0	1.0284	1027.5	7.11	73.1	0.610	7.30	75.0	0.626	7.58	77.9	0.650	7.92	81.4	0.679
5.0	1.0357	1034.8	8.85	91.6	0.764	9.05	93.6	0.781	9.34	96.7	0.807	9.67	100.1	0.835
6.0	1.0432	1042.3	10.63	110.8	0.925	10.83	112.9	0.942	11.08	115.5	0.964	11.41	118.9	0.992
7.0	1.0507	1049.8	12.40	130.2	1.087	12.60	132.3	1.104	12.87	135.1	1.127	13.17	138.3	1.154
8.0	1.0584	1057.5	14.19	150.0	1.252	14.37	152.0	1.268	14.64	154.8	1.292	14.95	158.1	1.320
9.0	1.0662	1065.3	15.97	170.1	1.419	16.15	172.0	1.435	16.42	174.9	1.460	16.71	178.0	1.485
10.0	1.0741	1073.2	17.75	190.5	1.590	17.93	192.4	1.606	18.16	194.9	1.626	18.45	198.0	1.652
11.0	1.0821	1081.2	19.52	211.0	1.761	19.68	212.8	1.776	19.93	215.5	1.798	20.20	218.4	1.822
12.0	1.0902	1089.2	21.29	231.9	1.935	21.46	233.7	1.950	21.69	236.2	1.971	21.97	239.3	1.997
13.0	1.0985	1097.5	23.08	253.3	2.114	23.23	255.0	2.128	23.47	257.6	2.150	23.74	260.5	2.174
14.0	1.1069	1105.9	24.86	274.9	2.294	25.02	276.7	2.309	25.24	279.1	2.239	25.50	282.0	2.353
15.0	1.1154	1114.4	26.62	296.7	2.476	26.80	298.7	2.493	27.02	301.1	2.513	27.26	303.8	2.535
16.0	1.1240	1123.0	28.40	318.9	2.661	28.56	320.7	2.676	28.77	323.1	2.696	29.02	325.9	2.720
17.0	1.1328	1131.8	30.17	341.5	2.850	30.33	343.3	2.865	30.51	345.3	2.882	30.78	348.4	2.907
18.0	1.1417	1140.7	31.94	364.4	3.041	32.10	366.2	3.056	32.30	368.4	3.074	32.54	371.2	3.098
19.0	1.1508	1149.8	33.74	387.9	3.237	33.87	389.4	3.250	34.05	391.5	3.267	34.29	394.3	3.290
20.0	1.1600	1159.0	35.50	411.5	3.434	35.64	413.1	3.447	35.83	415.3	3.466	36.04	417.7	3.486
21.0	1.1694	1168.4	37.28	435.6	3.635	37.40	437.0	3.647	37.59	439.2	3.665	37.82	441.9	3.688
22.0	1.1789	1177.9	39.05	459.9	3.838	39.19	461.6	3.852	39.37	463.7	3.870	39.58	466.2	3.890
23.0	1.1885	1187.5	40.81	484.6	4.044	40.97	486.5	4.060	41.15	488.7	4.070	41.36	491.2	4.099
24.0	1.1983	1197.3	42.58	509.8	4.254	42.76	512.0	4.273	42.94	514.1	4.290	43.13	516.4	4.309
25.0	1.2083	1207.3	44.37	535.6	4.470	44.52	537.4	4.485	44.69	539.5	4.502	44.88	541.8	4.521

Table 3-B. Computed Data for Aqueous Suspensions of Sweetpotato Starch Showing the Relationship Between Baumé and Starch Concentration at Different Suspension Temperatures

Baumé of Starch Suspension	Specific Gravity at 15°C. Equivalent to Baumé	Weight of 1 Liter of Starch Suspension (Grams)	Starch Concentrations at Indicated Suspension Temperatures											
			35°C.			40°C.			45°C.			50°C.		
			Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon	Percent by Weight	Grams per Liter	Pounds per Gallon
0.0	1.0000	999.1	1.33	13.3	0.111	1.78	17.8	0.149	2.28	22.8	0.190	2.79	27.9	0.233
1.0	1.0069	1006.0	3.08	31.0	0.259	3.52	35.4	0.295	4.00	40.2	0.335	4.50	45.3	0.378
2.0	1.0140	1013.1	4.81	48.7	0.406	5.25	53.2	0.444	5.73	58.0	0.484	6.23	63.1	0.527
3.0	1.0211	1020.2	6.56	66.9	0.558	6.99	71.3	0.595	7.46	76.1	0.635	7.95	81.1	0.677
4.0	1.0284	1027.5	8.30	85.3	0.712	8.72	89.6	0.748	9.18	94.3	0.787	9.67	99.4	0.829
5.0	1.0357	1034.8	10.03	103.8	0.866	10.47	108.3	0.904	10.92	113.0	0.943	11.40	118.0	0.985
6.0	1.0432	1042.3	11.80	123.0	1.026	12.20	127.2	1.061	12.63	131.6	1.098	13.11	136.6	1.140
7.0	1.0507	1049.8	13.53	142.0	1.184	13.96	146.6	1.223	14.38	151.0	1.260	14.85	155.9	1.300
8.0	1.0584	1057.5	15.30	161.8	1.350	15.70	166.0	1.385	16.11	170.4	1.422	16.59	175.4	1.464
9.0	1.0662	1065.3	17.07	181.8	1.517	17.46	186.0	1.552	17.86	190.3	1.588	18.34	195.4	1.631
10.0	1.0741	1073.2	18.80	201.8	1.684	19.18	205.8	1.717	19.58	210.1	1.753	20.02	214.9	1.793
11.0	1.0821	1081.2	20.53	222.0	1.853	20.92	226.2	1.888	21.30	230.3	1.922	21.76	235.3	1.964
12.0	1.0902	1089.2	22.30	242.9	2.027	22.67	246.9	2.060	23.03	250.8	2.093	23.50	256.0	2.136
13.0	1.0985	1097.5	24.06	264.1	2.204	24.42	268.0	2.236	24.79	272.1	2.271	25.23	276.9	2.311
14.0	1.1069	1105.9	25.83	285.7	2.384	26.18	289.5	2.416	26.52	293.3	2.448	26.97	298.3	2.489
15.0	1.1154	1114.4	27.58	307.4	2.565	27.93	311.3	2.598	28.26	314.9	2.628	28.70	319.8	2.669
16.0	1.1240	1123.0	29.33	329.4	2.749	29.68	333.3	2.781	30.00	336.9	2.811	30.42	341.6	2.851
17.0	1.1328	1131.8	31.07	351.7	2.935	31.40	355.4	2.966	31.73	359.1	2.997	32.13	363.6	3.034
18.0	1.1417	1140.7	32.83	374.5	3.125	33.13	377.9	3.154	33.46	381.7	3.185	33.85	386.1	3.222
19.0	1.1508	1149.8	34.56	397.4	3.316	34.88	401.1	3.347	35.18	404.5	3.376	35.57	409.0	3.413
20.0	1.1600	1159.0	36.31	420.8	3.512	36.62	424.4	3.542	36.92	427.9	3.571	37.30	432.3	3.608
21.0	1.1694	1168.4	38.06	444.7	3.711	38.36	448.2	3.740	38.65	451.6	3.769	39.00	455.7	3.803
22.0	1.1769	1177.9	39.83	469.2	3.915	40.10	472.3	3.941	40.40	475.9	3.971	40.75	480.0	4.006
23.0	1.1885	1187.5	41.59	493.9	4.122	41.86	497.1	4.148	42.13	500.3	4.175	42.48	504.5	4.210
24.0	1.1983	1197.3	43.36	519.1	4.332	43.62	522.3	4.359	43.90	525.6	4.386	44.23	529.6	4.420
25.0	1.2083	1207.3	45.08	544.2	4.541	45.34	547.3	4.567	45.60	550.5	4.594	45.93	554.5	4.627